Edge Protection by Zinc

Product Development Centre

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Product Development Technical Digest

British Steel Corporation

Edge Corrosion? Zinc Protects

In any discussion on the prospect of using pre-galvanised steel sheet, the question of cut-edge corrosion is almost invariably raised. Why 'edge corrosion?' 'Edge protection' is the correct reference, since it is a long-established fact that the presence of a zinc coating on the surface of steel sheet reliably protects exposed edges — or areas of local damage — by an automatic process of electrochemical action.

Nevertheless, technically feasible applications for galvanised steel sheet are still resisted on the basis of a traditional inhibition which is often completely groundless.

The British Steel Corporation has been aware of this problem for a long time and has produced various articles and leaflets designed to allay fears regarding this 'bête noire' of edge corrosion. A five-year long investigation into this subject has provided actual quantitative data. The aim of this Digest is to give a broad review of the basic facts of edge protection by zinc and to present a summary of the research results.

It is unnecessary within the context of this article to discuss in detail the technicalities of the protective processes which operate in a pre-galvanised steel sheet. It is sufficient to say that zinc protects steel in two distinct ways:

1. As a long-lived barrier
The corrosion rate of zinc in most UK atmospheric conditions is only one-tenth to one-thirtieth the rate of mild steel. Furthermore, if the zinc surface is painted — as, for example, BSC Colorcoat — then the protective effect of the multi-layer coating is synergistic, i.e. the life of painted, zinc coated steel such as the BSC Colorcoat range is longer than the lives of zinc coated steel and painted mild steel added together.

2. By galvanic protection across small bare areas, e.g. cut edges
When two dissimilar metals are in electrical contact in the presence of a conducting medium (moisture), galvanic corrosion of one takes place while the other is protected. The more reacitve of the two metals will become the anode in a natural electrical cell and, if the anode does not form an insoluble high-resistance oxide film (which zinc does not), will oxidise and produce electrical current to protect the cathode from corrosion. Thus zinc protects steel by galvanic action because it is anodic to steel at normal ambient temperatures.

Laboratory evidence of the galvanic protection afforded by a zinc coating is given in the photographs, Figs. 1 and 2, which show a panel of acrylic painted galvanised steel, specially scribed through to the steel base, and a panel of mild steel similarly scribed. Both were subjected to a salt spray test to DEF 1053 (comparable with ASTM-B117).

The galvanic protection of the zinc is apparent from the maintained paint adhesion and absence of red rust on the scribe marks and cut edges of the sample shown in Fig. 1; the mild steel sample, Fig. 2, shows extensive rusting.

It is often difficult, however, to reassure prospective users of galvanised steel on the sole evidence of laboratory tests. Fortunately data is also available from long-term atmospheric exposure trials — field tests which have added greatly to our appreciation of the very significant protection afforded by zinc at cut edges.

Field Testing

In order to confirm the results of qualitative laboratory tests with quantitative data, the British Steel Corporation has collated the results of a five-year series of atmospheric exposure tests designed specifically to investigate the degree of protection given by zinc at cut edges and at breaks in the coating.

In this work, specimens of continuously galvanised steel of different thicknesses and various coating weights were prepared with both sheared and milled edges. In addition the galvanised surface of each panel was scored with parallel milled grooves of different widths, through the coating to the steel base. These specimens were then exposed for up to five years at several sites throughout the UK to determine the extent of corrosion.

The results of these trials are extensive, and for a complete analysis one should consult BSC Product Development Centre at the address shown on the back cover; the major conclusions are as follows:

1. That cut edges of pre-galvanised steel sheet up to 3mm thick will behave well under normal conditions of free exposure at all angles of exposure.

2. That cut edges will stain, but there will be little or no creep back of corrosion for at least five years, even in an urban atmosphere. If the cut is facing upward, rust-staining may be significant; but the actual extent of the corrosive attack is no greater that when the edge points downward since top edges do not retain moisture.

3. If the exposure conditions are mild — as, for example, in inland rural areas — significant corrosion at a cut edge is unlikely to occur in less than five years for sheets of up to 3mm thickness, provided coating weight exceeds about 275g/m² total both sides.

Note that BS2989 Class G275 specifies 275g/m² as a minimum. Moreover, the drier the atmosphere and/or the heavier the zinc coating, the longer the life.

4. If paint or other coatings are applied over the zinc, the life expectancy will rise still further. If the coating is maintained, a very long life indeed can be expected.

In the BSC investigation, the most severe exposure test site used was at a railway yard in Stratford, East London. The photomicrograph Fig. 3, shows the condition of milled grooves in samples exposed for five years at this site. It can be seen from the photograph that a 300g/m² coating has effectively protected a milled groove 1.6mm wide.

The width of the groove protected is determined by the thickness of the coating adjacent to the groove or cut edge rather than by the area of the coating: the thicker the coating, the greater its 'throwing power' across a gap. For instance, a coating weight of 600g/m² (BS2989 Class G600) affords protection for up to 3.2mm, i.e. up to the maximum gauge of hot-dip pre-galvanised steel (Galvatite) produced by BSC. The photograph, Fig. 4, shows the condition of the milled grooves in typical Class G600 material after five years exposure at Stratford, East London.

Further evidence of the protective power of zinc coatings, as revealed by long-term field tests, is shown in photographs, Figs. 5 and 6. Fig. 5 shows the condition of a galvanised steel (Galvatite IZ) section exposed for four and a half years in a severe marine environment less than two miles from a major steelworks. There is little or no creep-back of rust from the cut edges, despite the light coating weight of the section — only 180g/m². Fig. 6 shows painted galvanised steel panels which have been exposed for fifteen months on the deck of a container ship plying between the UK and the Far East. During this time these samples were subjected to extremes of humidity and temperature and even to actual sea wash. Again, little or no edge failure is apparent. It is also interesting that Fig. 6 includes sample panels containing arc welds — often claimed as corrosion risks in arguments against galvanised steel. These welds were dressed with a zinc-rich paint before the finishing paint and before test exposure. It should be noted that these weldment areas show no evidence of premature corrosion.

Field and laboratory tests thus demonstrate the high degree of edge protection afforded by a zinc coating to steel sheet. Pre-galvanised steels have been used for many years in severe outside environments also, usually with a paint or PVC coating. The multi-layer coating is required to maintain not only protection against corrosion but also a high aesthetic standard. For the latter requirement, unsightly cut edges would not be acceptable. Such experience also provides useful, practical examples of edge protection.

Application Experience

Although it is accepted that accelerated laboratory tests provide valuable pointers to the likely performance of a material in any given application, these tests do not provide conclusive proof.

Long-term field trials such as those described yield further evidence, but are likewise not conclusive. In the final analysis, the results from an actual exposure situation are necessary.

A particularly useful example of an application where coated galvanised sheet with cut edges has been exposed for over ten years in an aggressive environment is shown in Figs. 7 to 9. These show cladding sheets in BSC PVC-coated hot-dip galvanised steel (BS2989 Class G275) used on the Ford Motor Co. Parts Depot at West Thurrock, Essex — a highly corrosive environment by the lower tidal reaches of the Thames and close to a power station and a cement works. As can be seen, this atmosphere has produced no significant corrosion on the bottom cut edges of the sheets. Fixing holes on the same building — another so-called danger point for edge corrosion — still show no sign of rust, such as surface staining, even after such a long period (Figs. 8 and 10). It is obvious that zinc coatings on steel provide a very effective automatic protection against corrosion at cut edges. Nevertheless, a proper awareness of the basic mechanics of edge protection enables the designer or production engineer to reduce any remaining risk to a minimum by attention to detail.

Practical aspects of fabrication and design should be decided with edge protection in mind.

Practical Aspects

1. The 'Drag-over' effect
Although it has been established that zinc provides effective and long-lasting protection at cut edges, it has also been demonstrated that the protection afforded to an exposed area will depend, for any given thickness of zinc, on the width of the unprotected area. The thinner the cut edge, the better the degree of protection. Processes such as shearing or punching — unlike sawing or drilling — drag the zinc over the cut edge and thus reduce the actual unprotected area. The extent to which zinc is smeared over a sheared galvanised steel edge can be substantial as is illustrated in the X-ray distribution images, Figs. 12 to 14, which refer to the edge shown in the photomicrograph, Fig.11. The choices of shearing and punching as cutting methods are obviously preferable where practical.

2. Edge detail
Corrosion of the cut edges is unlikely to proceed beyond a superficial rusting of the bare steel which quickly becomes self-smothering. Such corrosion does not detract from the structural integrity of the component, but in some cut-edge situations it may cause an aesthetically unacceptable staining of the sheet surface. In these circumstances the use of protective — and decorative — edging pieces or the strategic folding or designing-out of the exposed edge should be considered. Some possible details are shown in Fig. 15.

Conclusions

The theory that the zinc protects cut edges on pre-galvanised steel sheet has now been proved in practice by extensive testing and experience. In the vast majority of applications, therefore, edge corrosion is unlikely to be a significant problem for users of BSC Galvatite and BSC Colorcoat products on a Galvatite substrate.[1] However, if Galvatite is to be used in particularly aggressive conditions, e.g. the use of Galvatite or pre-painted Galvatite (BSC Colorcoat) for roofing panels installed at very low pitches (<4°) or for applications in chemically polluted environments, please consult the Product Development Centre.

The BSC Product Development Centre

BSC Product Development Centre provides a service to users and potential users of coated steel sheet. The Centre includes a Field Unit whose specialist engineers are available to discuss possible applications with specifiers in many industries. There is also a Product Engineering section which assists in the design and fabrication of coated steel products, maintains a sample warehouse and can offer a prototype manufacturing service.

The Product Development Centre will be pleased to assist in developing applications for coated steel sheet and to advise on choice of material for any particular project. For further information, please contact:

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1. The coating on BSC Zalutite hot-dip zinc-aluminium alloy coated steel contains 45% zinc (by weight) which also gives edge protection. For more information, please consult BSC at the address on the back cover.

Fig. 1 Acrylic painted galvanised steel — Panel scribed through to steel substrate and salt spray tested to DEF 1053.

Fig. 2 Acrylic painted mild steel — Panel scribed through to steel substrate and salt spray tested to DEF 1053.

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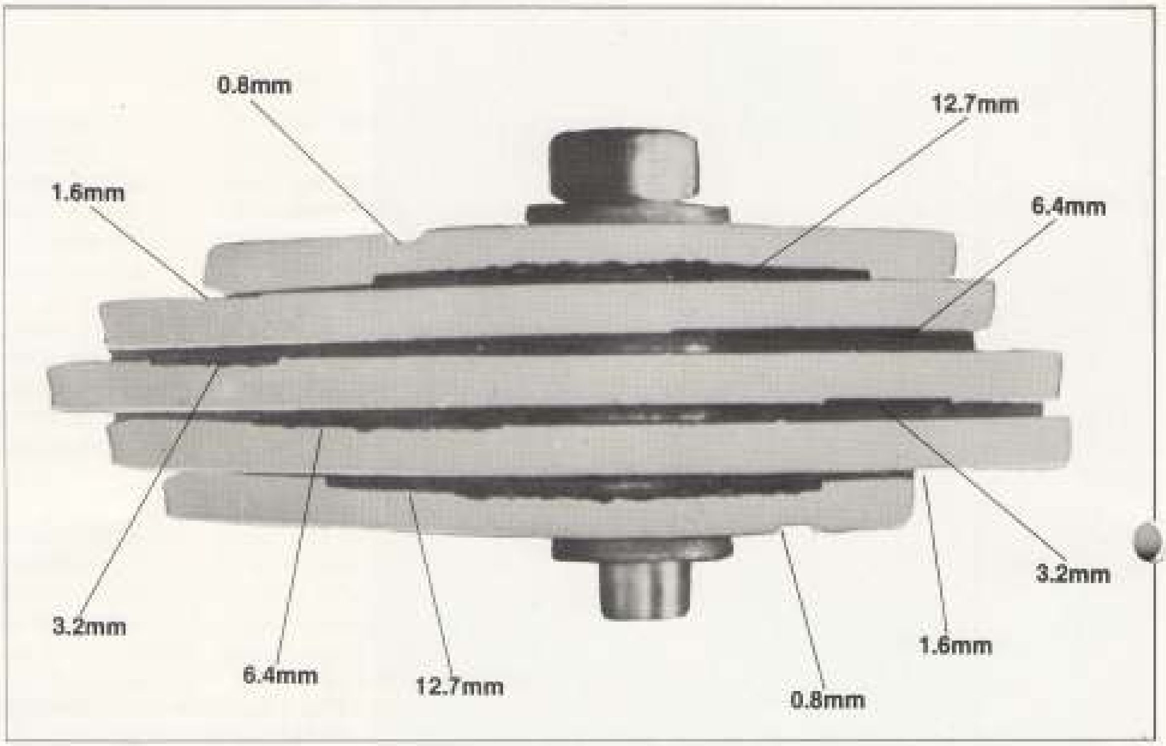

Fig. 3 Micro-section showing the condition of milled grooves in galvanised steel (coating weight 300g/m²) exposed for 5 years at Stratford, East London.

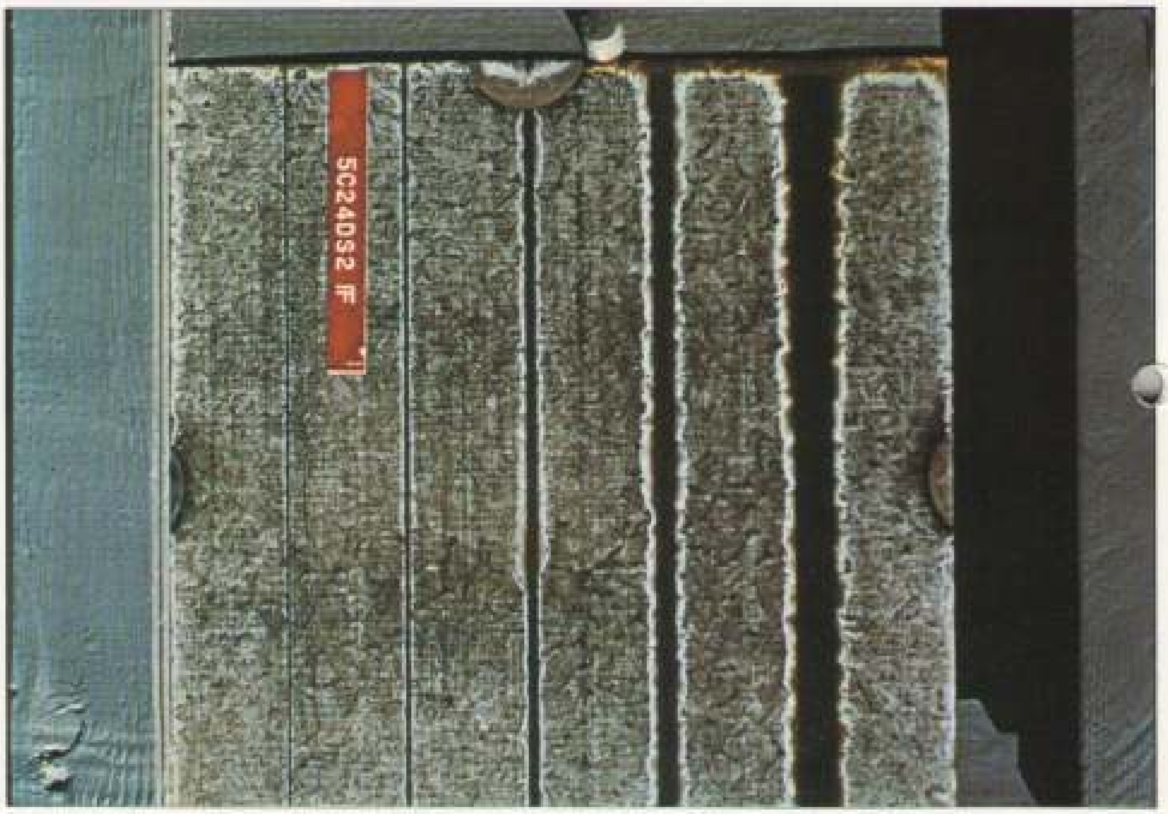

Fig. 4 Hot-dip pre-galvanised panel ('Galvatite') — BS 2989 Class G600 (coating weight 600g/m²) after 5 years exposure at Stratford, showing protection of milled grooves up to 3.2mm wide.

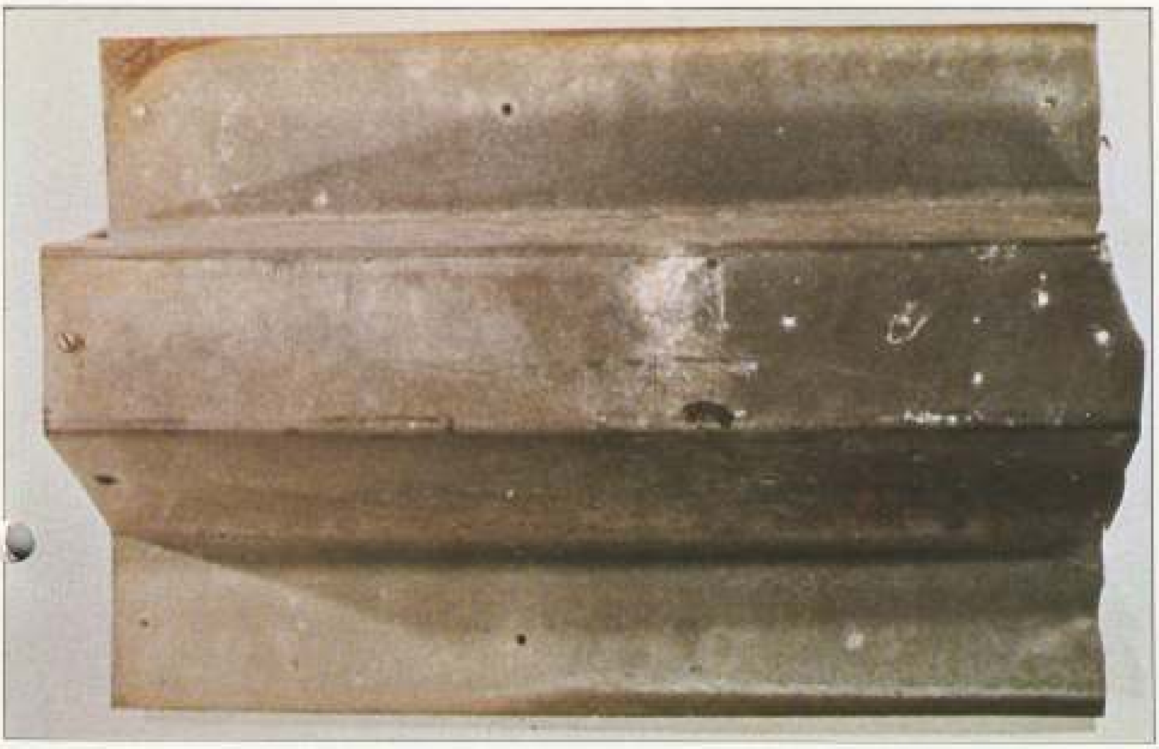

Fig. 5 'Galvatite IZ' — coating weight 180g/m² — box section exposed for 4½ years in a severe marine environment, with cut edges also exposed.

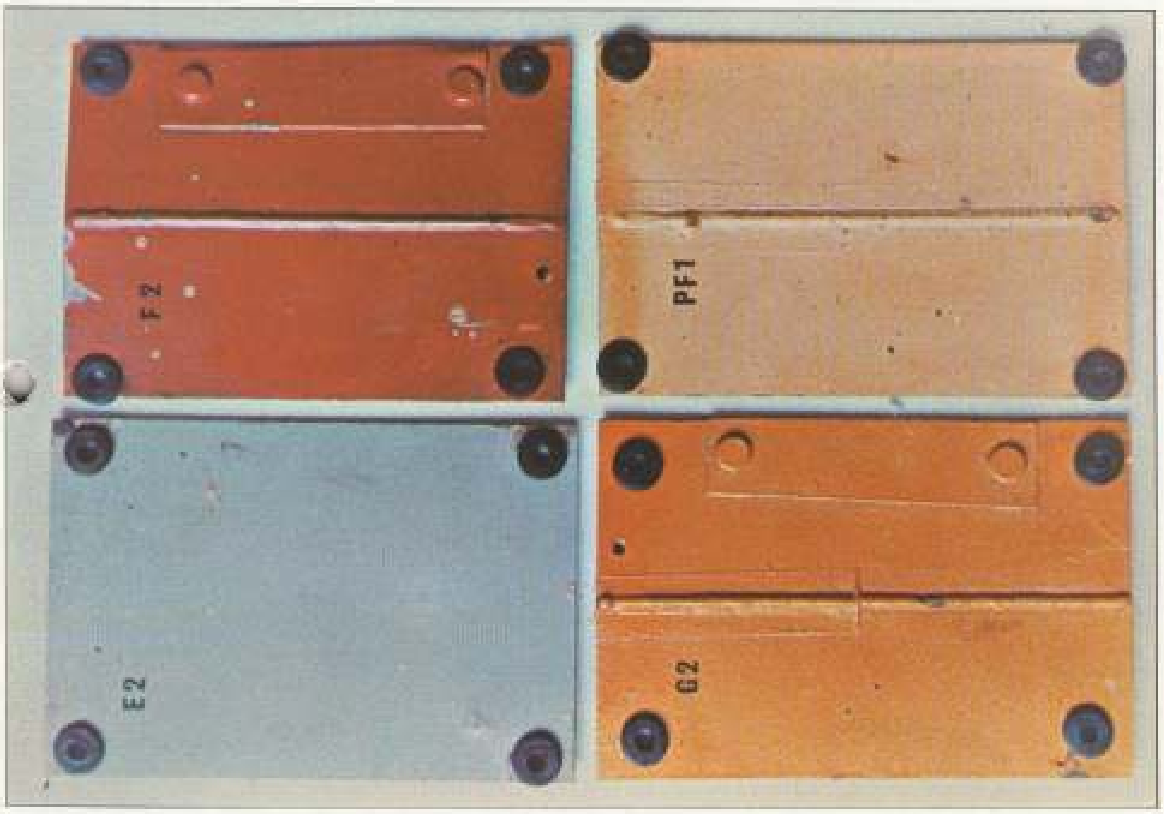

Fig. 6 Painted galvanised steel panels exposed for 15 months on the deck of a container ship operating on rigorous UK-Far East routes.

Fig. 7 Ford Motor Company Parts Depot at West Thurrock, Essex.

Fig. 8 Bottom edge of PVC-coated hot-dip galvanised steel cladding used on the Ford Motor Company Depot at West Thurrock and photographed ten years after erection.

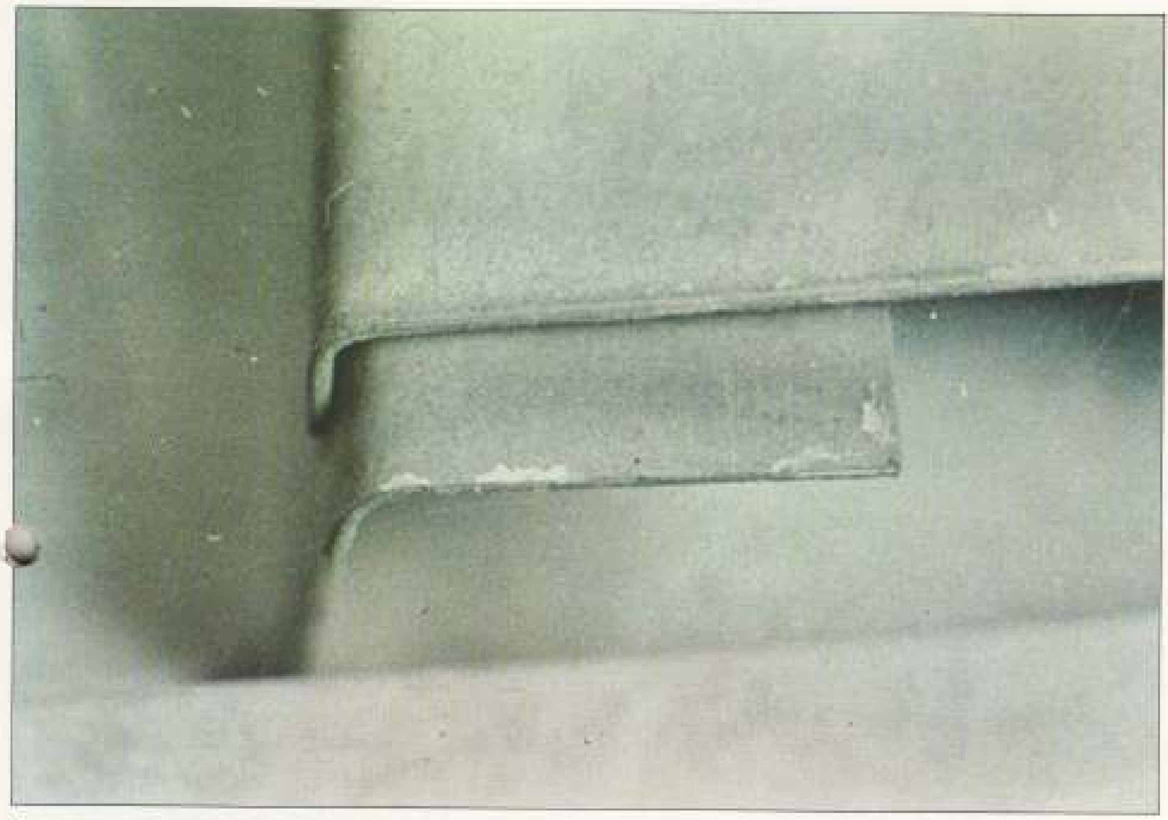

Fig. 9 Close-up of cut edge on Ford Motor Company Depot showing effective protection by zinc 10 years after erection.

Fig. 10 Fixing holes on Ford Motor Company Depot — a potential danger point for corrosion, still in excellent condition after 10 years.

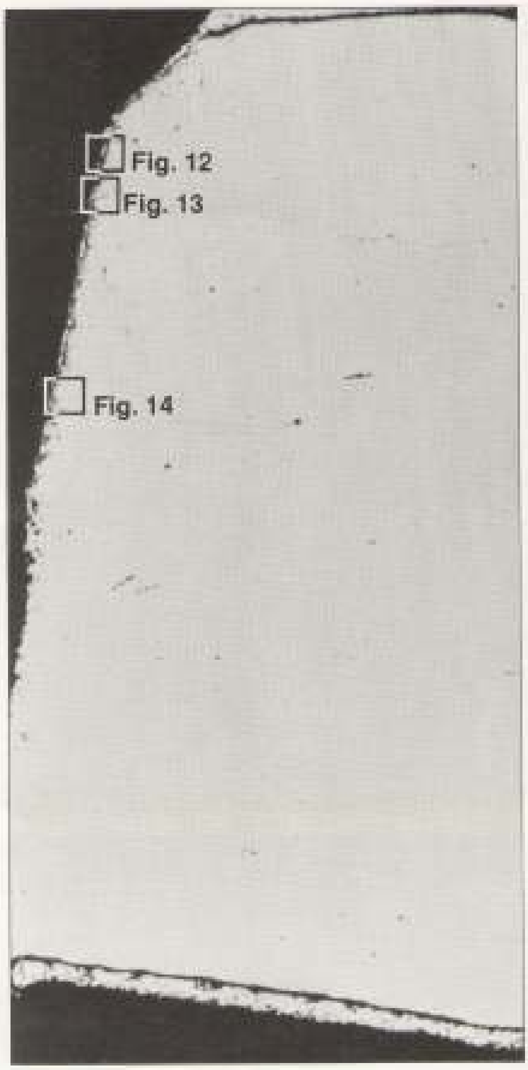

Fig. 11 Photograph of sheared edge in galvanised steel to BS 2989 Class G275 — minimum specification 275g/m².

Fig. 12

Fig. 13

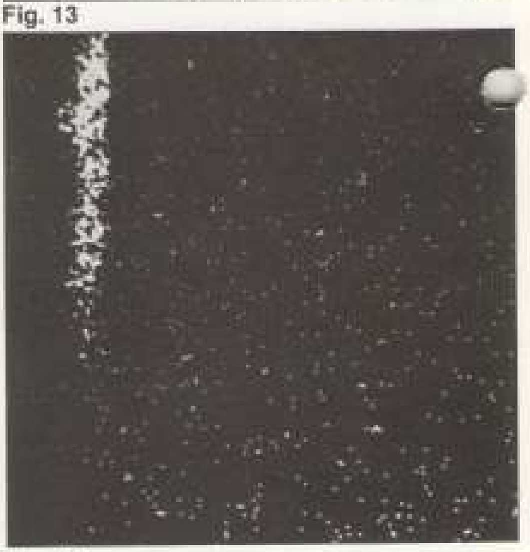

Fig. 14

Figs. 12-14 X-Ray distribution images confirming the presence of a zinc smear on a galvanised steel sheared edge 1.2mm thick.

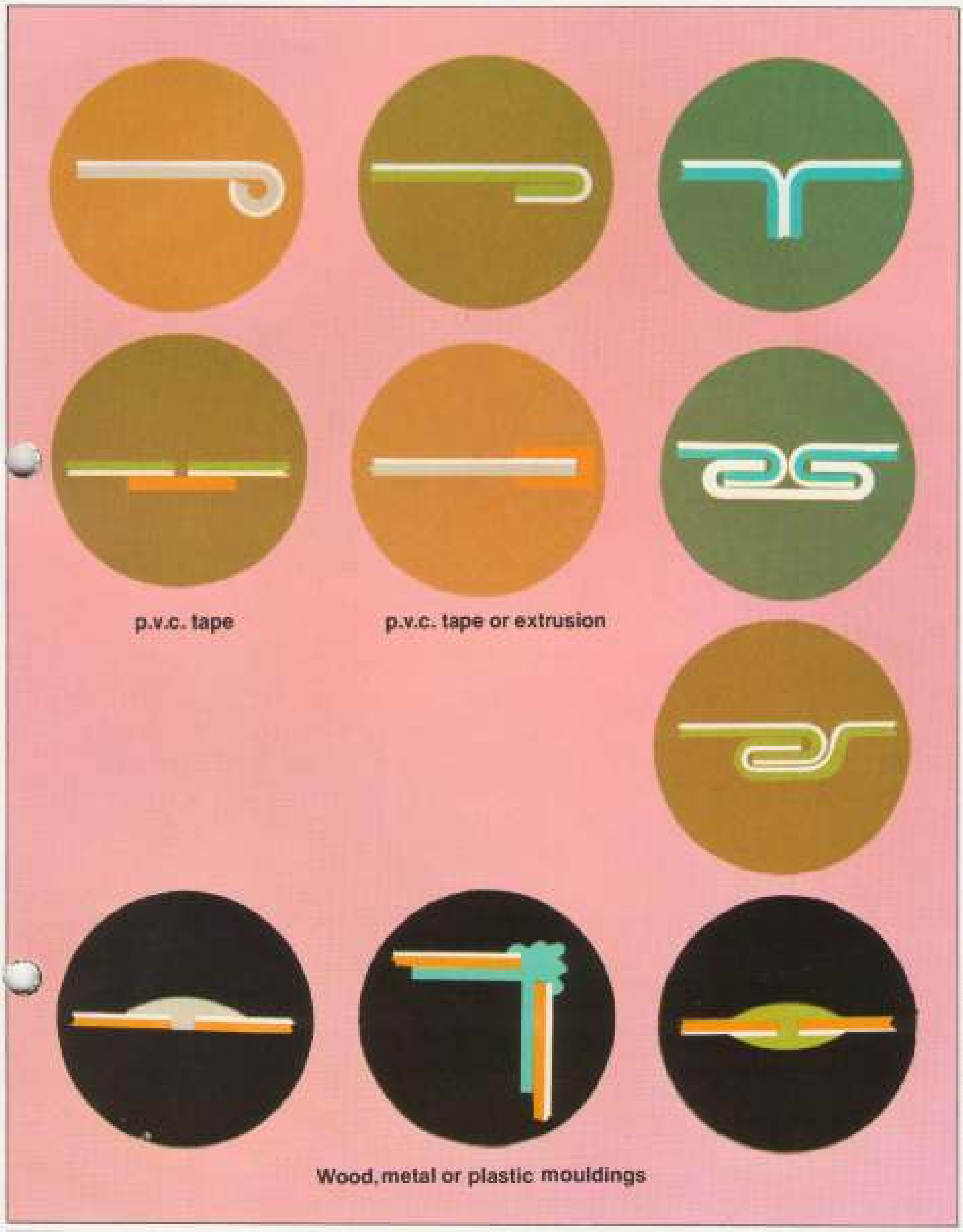

Fig. 15 Where rust staining arising from the superficial corrosion of a cut edge would be aesthetically unacceptable, this can be avoided by strategic design. Edges may be protected by the use of trims or adhesive tapes; these can also be used for decoration. Alternatively, returned or rolled flanges may conceal cut edges and help to protect them.

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